

WHAT IS CLAIMED IS:

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1. A magnetoresistive effect element comprising:

a magnetoresistive effect film including a magnetization-pinned layer having a magnetic film pinned in magnetization substantially in one direction, a magnetization free layer having a magnetic film variable in direction of magnetization in response to an external magnetic field, and a nonmagnetic metal intermediate layer interposed between said magnetization-pinned layer and said magnetization free layer; and

a pair of electrodes electrically coupled to said magnetoresistive effect film to supply a current substantially perpendicularly to the film plane of said magnetoresistive effect film,

at least one of said magnetization-pinned layer, said magnetization free layer and said nonmagnetic metal intermediate layer including a first layer which contains a half-metal as a major component thereof and a second layer whose content of said half-metal is lower than said first layer.

2. A magnetoresistive effect element according to claim 1, wherein said half-metal is at least one of iron oxides having spontaneous magnetization, chromium oxides, and manganese oxides.

3. A magnetoresistive effect element according to claim 1, wherein said half-metal is at least one of  $\text{Fe}_3\text{O}_4$  oxides,  $\text{CrO}_2$  oxides

and manganites.

4. A magnetoresistive effect element according to claim 1, wherein said first layer is a continuous layer having an area ratio of pinholes not more than 15%.

5. A magnetoresistive effect element according to claim 1, wherein a thickness of said first layer is not less than 0.5 nm and not more than 5 nm.

6. A magnetoresistive effect element according to claim 1, wherein said magnetization-pinned layer includes said first layer and said second layer,

said second layer being made of Co, Fe or Ni, or said second layer including Co, Fe or Ni as a major component thereof.

7. A magnetoresistive effect element according to claim 6, wherein said second layer is provided between said first layer and said nonmagnetic metal intermediate layer.

8. A magnetoresistive effect element according to claim 1, wherein said magnetization free layer includes said first layer and said second layer whose magnetization direction varies in response to an external magnetic field more sensitively than said first layer.

9. A magnetoresistive effect element according to claim 1,

wherein said magnetization free layer includes said first layer and said second layer,

said second layer being made of Co, Fe or Ni, or said second layer including Co, Fe or Ni as a major component thereof.

10. A magnetoresistive effect element according to claim 8, wherein said second layer is provided between said first layer and said nonmagnetic metal intermediate layer.

11. A magnetoresistive effect element according to claim 8, wherein said first layer is provided between said second layer and said nonmagnetic metal intermediate layer.

12. A magnetoresistive effect element according to claim 1, wherein said magnetization free layer includes said first layer, said second layer and a third layer,

a magnetization direction of said second layer varying in response to an external magnetic field more sensitively than said first layer, and a magnetization direction of said third layer varying in response to an external magnetic field more sensitively than said first layer,

said first layer being provided between said second and third layers.

13. A magnetoresistive effect element according to claim 1, wherein said nonmagnetic metal intermediate layer includes said

first layer, said second layer made of a nonmagnetic metal and a third layer made of a nonmagnetic metal,

said first layer being provided between said second and third layers.

14. A magnetoresistive effect element comprising:

a magnetoresistive effect film including a magnetization-pinned layer having a magnetic film pinned in magnetization substantially in one direction, a magnetization free layer having a magnetic film variable in direction of magnetization in response to an external magnetic field, and a nonmagnetic metal intermediate layer interposed between said magnetization-pinned layer and said magnetization free layer; and

a pair of electrodes electrically coupled to said magnetoresistive effect film to supply a current substantially perpendicularly to the film plane of said magnetoresistive effect film,

a first layer which contains a half-metal as a major component thereof being interposed in at least one of a location between said magnetization-pinned layer and said nonmagnetic metal intermediate layer and a location between said magnetization free layer and said nonmagnetic metal intermediate layer.

15. A magnetoresistive effect element according to claim 14, wherein said half-metal is at least one of iron oxides having spontaneous magnetization, chromium oxides, and manganese oxides.

16. A magnetoresistive effect element according to claim 14, wherein said half-metal is at least one of  $\text{Fe}_3\text{O}_4$  oxides,  $\text{CrO}_2$  oxides and manganites.

17. A magnetoresistive effect element according to claim 14, wherein said first layer is a continuous layer having an area ratio of pinholes not more than 15%.

18. A magnetoresistive effect element according to claim 14, wherein a thickness of said first layer is not less than 0.5 nm and not more than 5 nm.

19. A magnetic head comprising a magnetoresistive effect element having:

a magnetoresistive effect film including a magnetization-pinned layer having a magnetic film pinned in magnetization substantially in one direction, a magnetization free layer having a magnetic film variable in direction of magnetization in response to an external magnetic field, and a nonmagnetic metal intermediate layer interposed between said magnetization-pinned layer and said magnetization free layer; and

a pair of electrodes electrically coupled to said magnetoresistive effect film to supply a current substantially perpendicularly to the film plane of said magnetoresistive effect film,

at least one of said magnetization-pinned layer, said

magnetization free layer and said nonmagnetic metal intermediate layer including a first layer which contains a half-metal as a major component thereof and a second layer whose content of said half-metal is lower than said first layer.

20. A magnetic head comprising a magnetoresistive effect element having:

a magnetoresistive effect film including a magnetization-pinned layer having a magnetic film pinned in magnetization substantially in one direction, a magnetization free layer having a magnetic film variable in direction of magnetization in response to an external magnetic field, and a nonmagnetic metal intermediate layer interposed between said magnetization-pinned layer and said magnetization free layer; and

a pair of electrodes electrically coupled to said magnetoresistive effect film to supply a current substantially perpendicularly to the film plane of said magnetoresistive effect film,

a first layer which contains a half-metal as a major component thereof being interposed in at least one of a location between said magnetization-pinned layer and said nonmagnetic metal intermediate layer and a location between said magnetization free layer and said nonmagnetic metal intermediate layer.

21. A magnetic reproducing apparatus which reads information magnetically recorded in a magnetic recording medium,

said magnetic reproducing apparatus comprising a

magnetoresistive effect element having:

a magnetoresistive effect film including a magnetization-pinned layer having a magnetic film pinned in magnetization substantially in one direction, a magnetization free layer having a magnetic film variable in direction of magnetization in response to an external magnetic field, and a nonmagnetic metal intermediate layer interposed between said magnetization-pinned layer and said magnetization free layer; and

a pair of electrodes electrically coupled to said magnetoresistive effect film to supply a current substantially perpendicularly to the film plane of said magnetoresistive effect film,

at least one of said magnetization-pinned layer, said magnetization free layer and said nonmagnetic metal intermediate layer including a first layer which contains a half-metal as a major component thereof and a second layer whose content of said half-metal is lower than said first layer.

22. A magnetic reproducing apparatus which reads information magnetically recorded in a magnetic recording medium,

a magnetoresistive effect film including a magnetization-pinned layer having a magnetic film pinned in magnetization substantially in one direction, a magnetization free layer having a magnetic film variable in direction of magnetization in response to an external magnetic field, and a nonmagnetic metal intermediate layer interposed between said magnetization-pinned layer and said magnetization free layer; and

a pair of electrodes electrically coupled to said magnetoresistive effect film to supply a current substantially perpendicularly to the film plane of said magnetoresistive effect film,

a first layer which contains a half-metal as a major component thereof being interposed in at least one of a location between said magnetization-pinned layer and said nonmagnetic metal intermediate layer and a location between said magnetization free layer and said nonmagnetic metal intermediate layer.



## ABSTRACT OF THE DISCLOSURE

In a CPP element using a metal intermediate layer excellent in shot noise and response to high frequencies unlike a TMR element,  
5 its magnetoresistive effect film includes a magnetic layer mainly made of a half-metal exhibiting ferromagnetism, ferrimagnetism or antiferromagnetism, and largely variable in way of conduction in response to spin direction of electrons.

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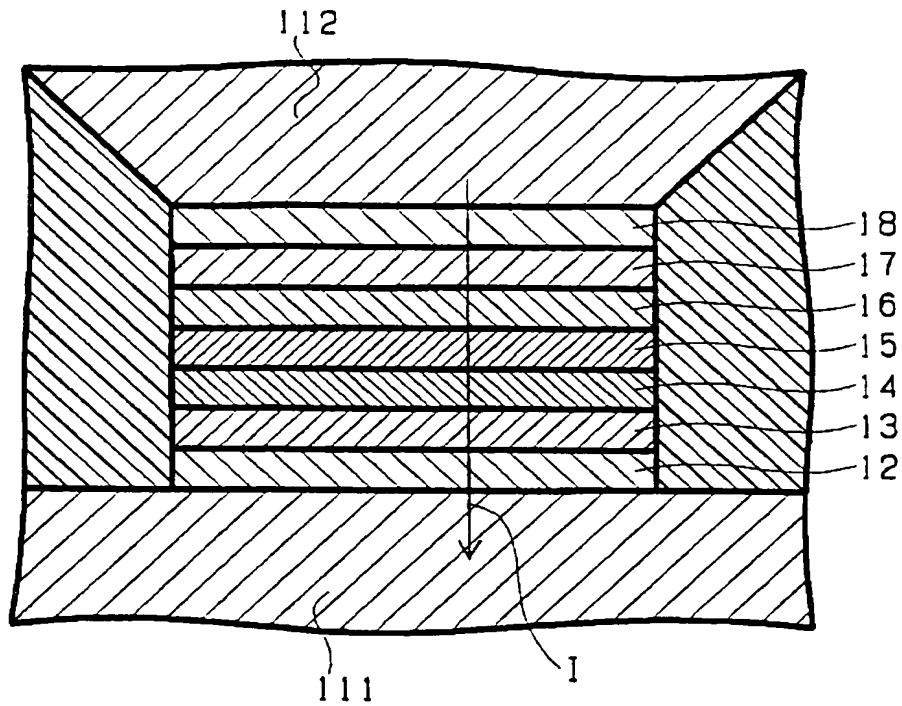


FIG. 1A

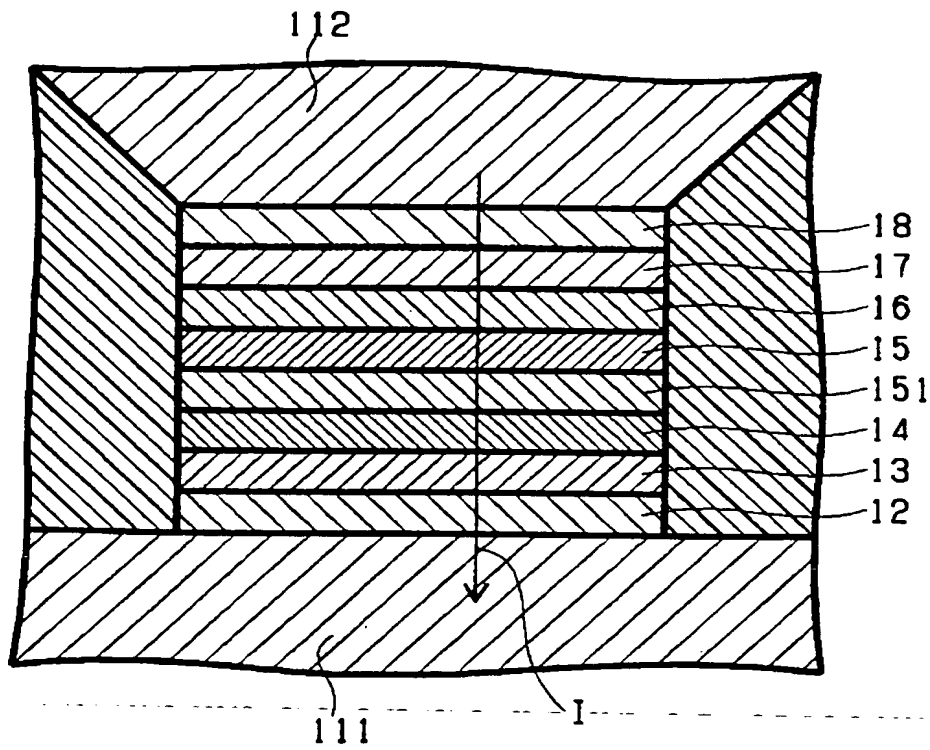
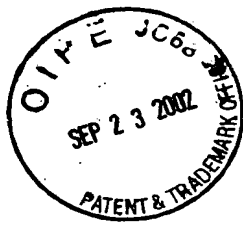


FIG. 1B



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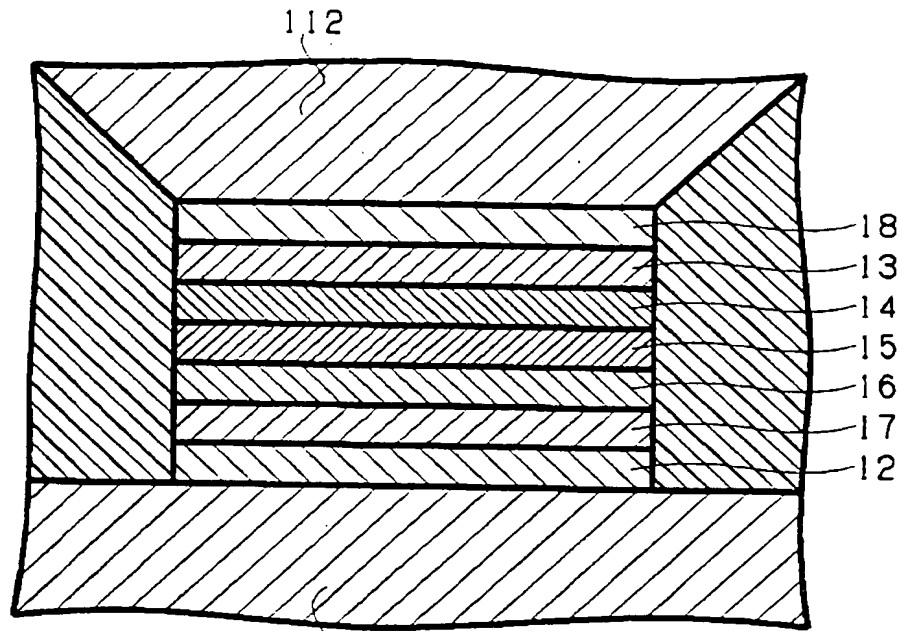


FIG. 2

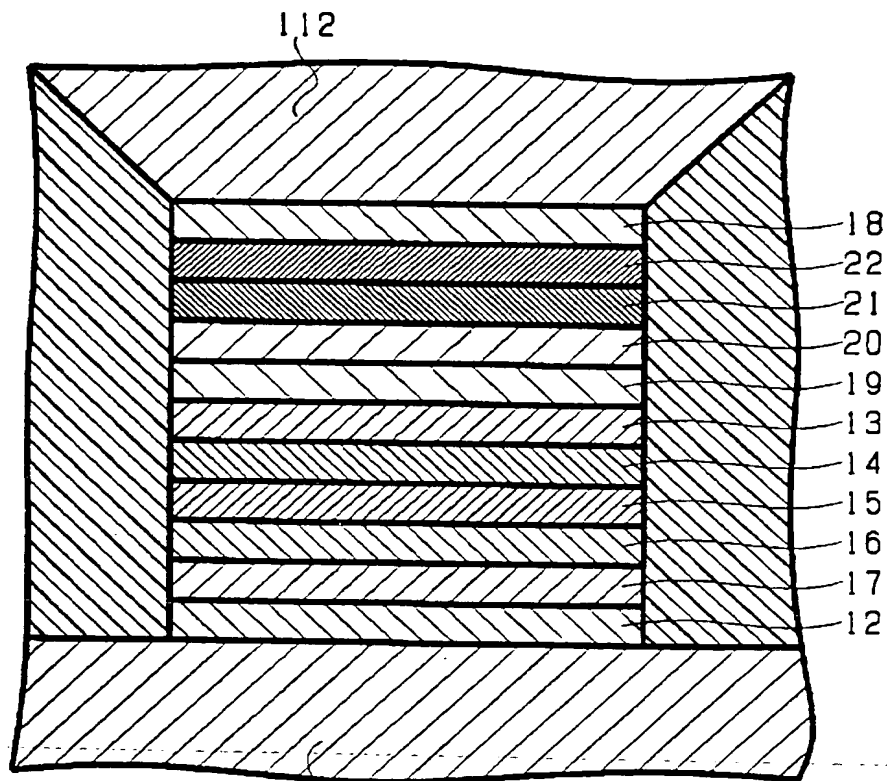
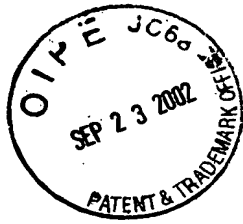


FIG. 3



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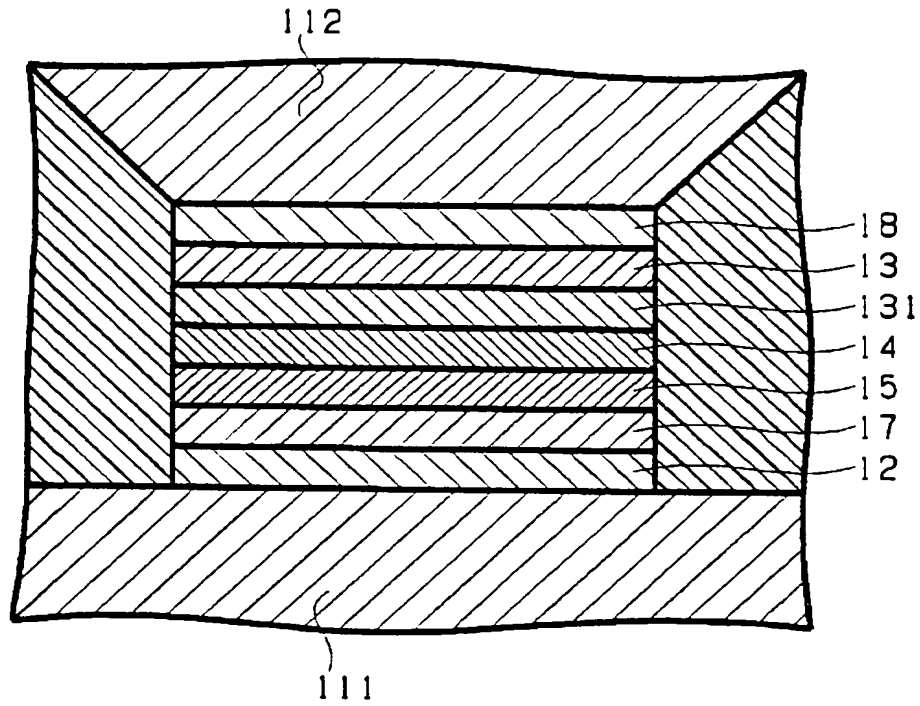


FIG. 4A

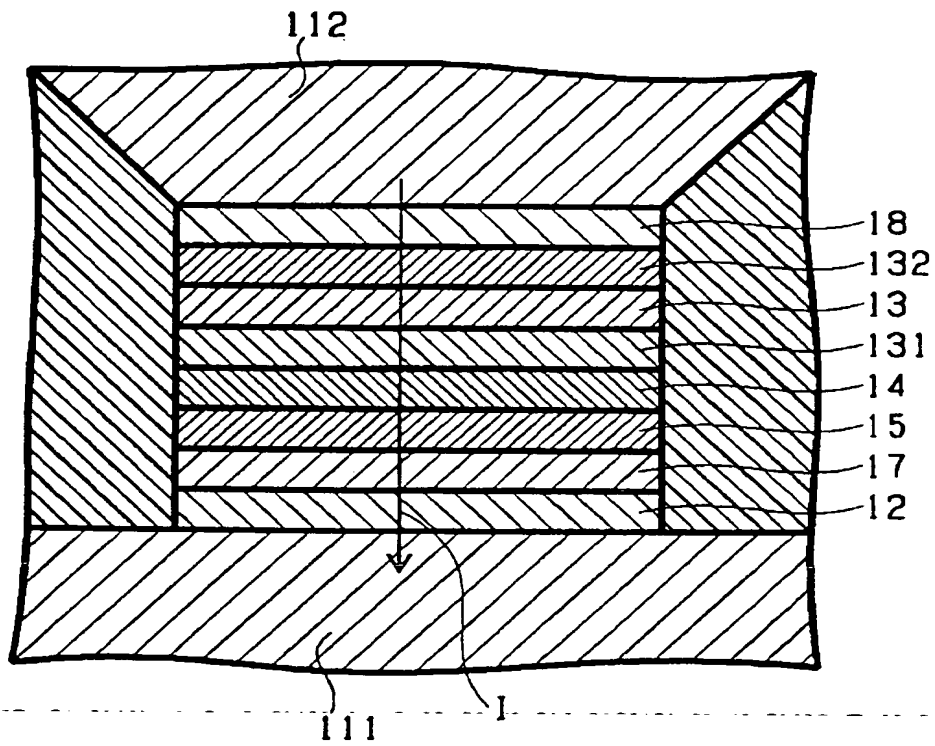
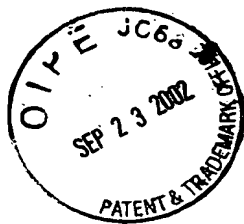


FIG. 4B



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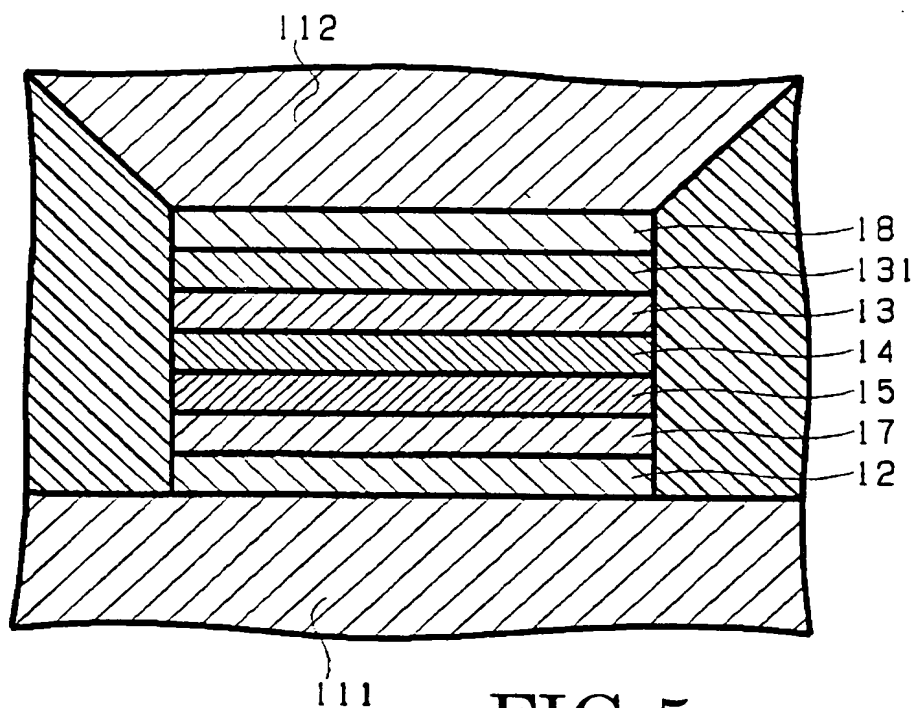


FIG. 5

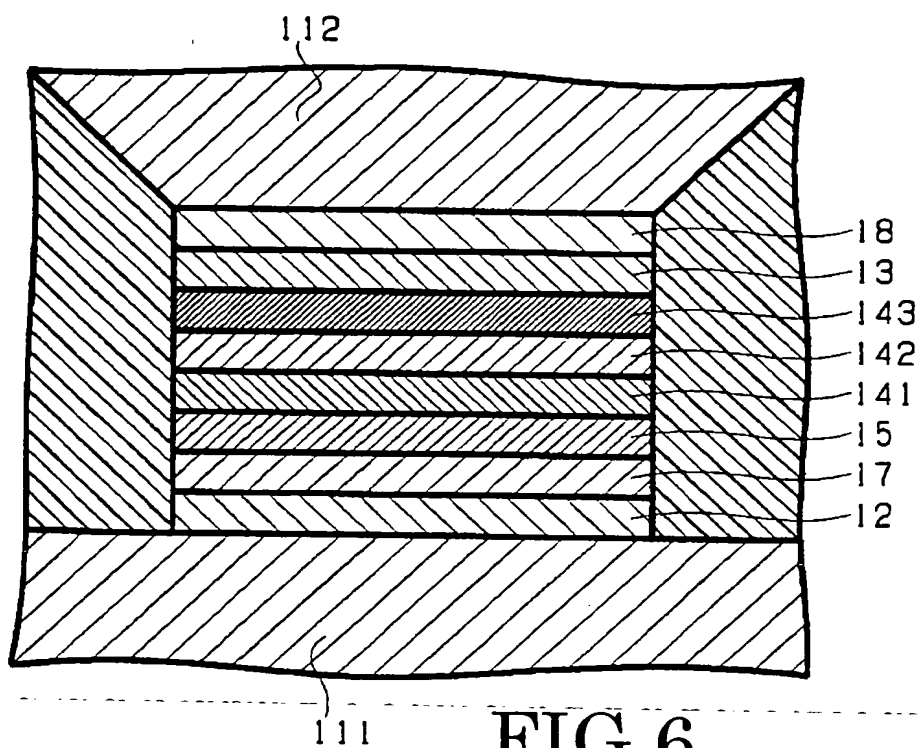
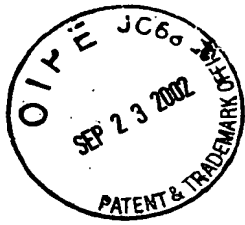


FIG. 6



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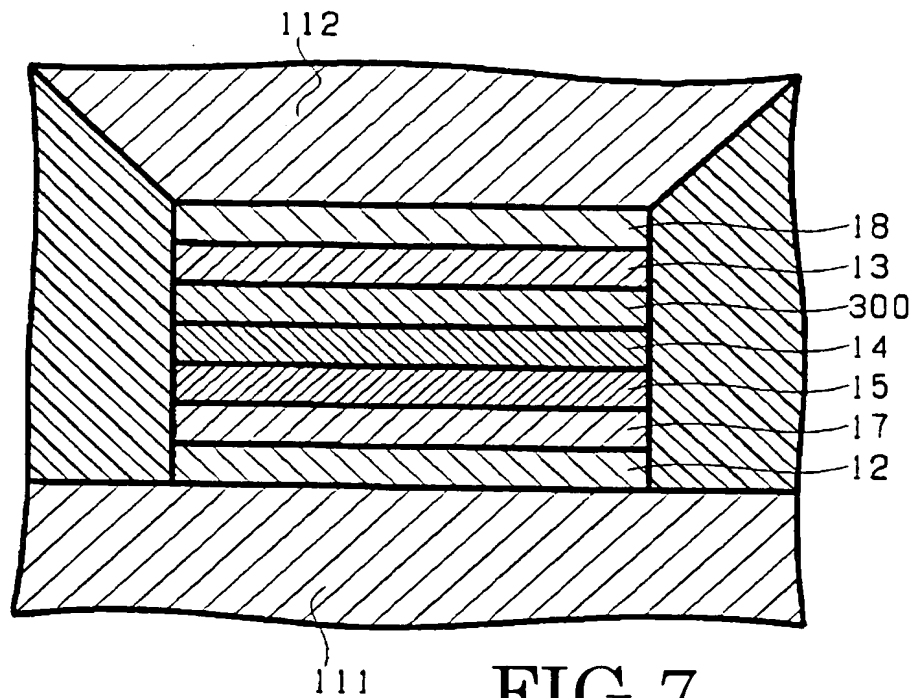


FIG. 7

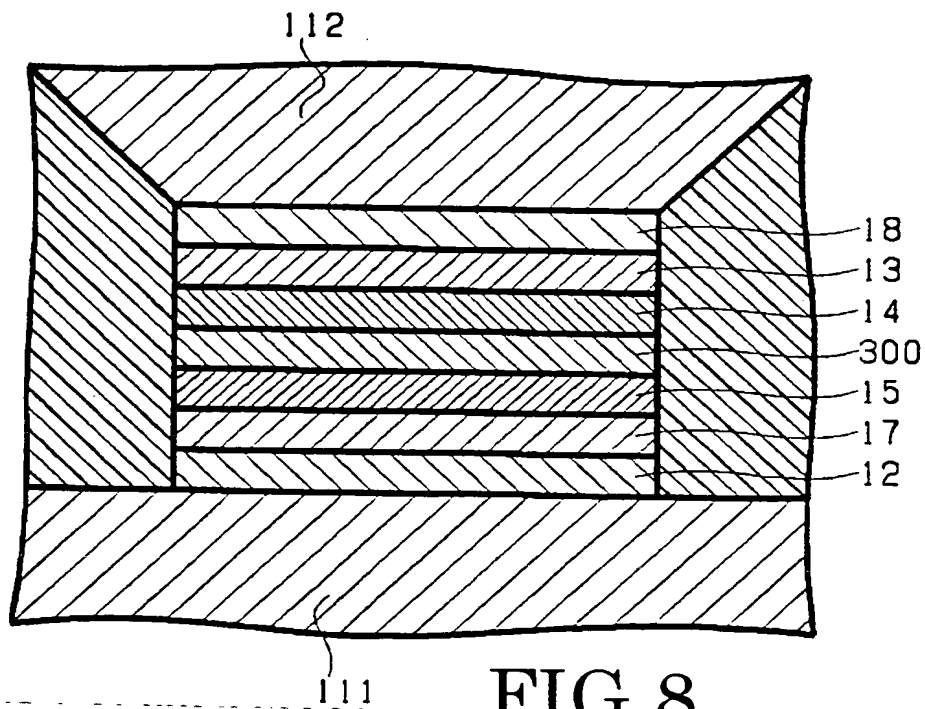
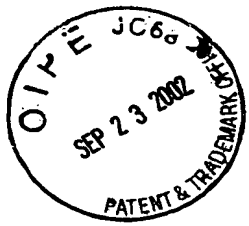


FIG. 8



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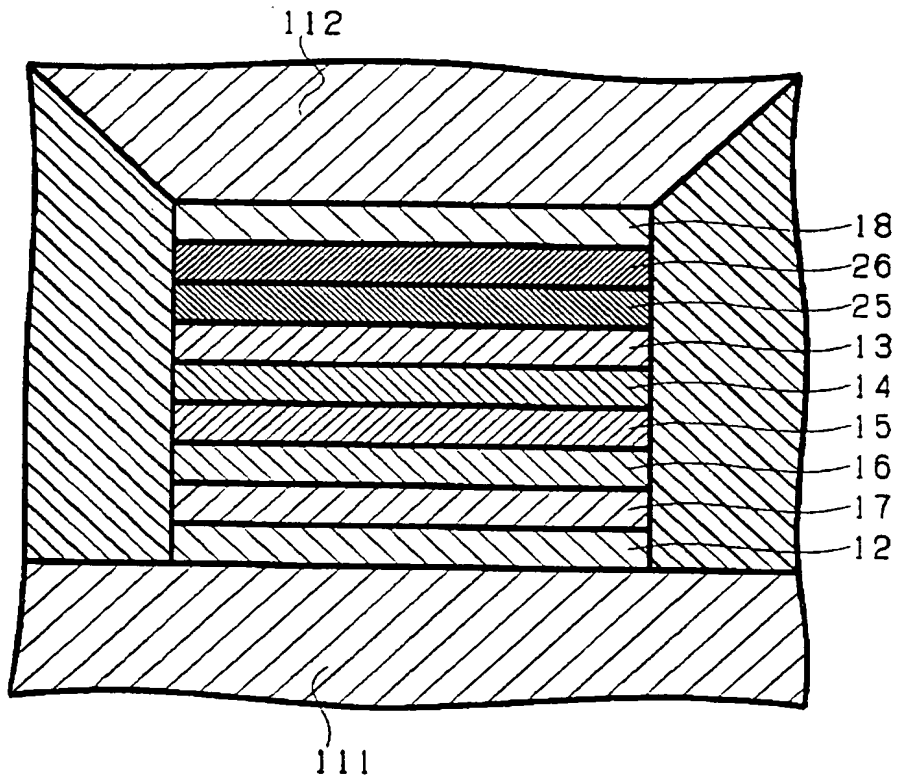
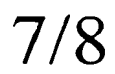
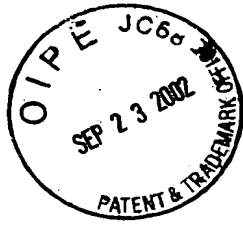


FIG.9







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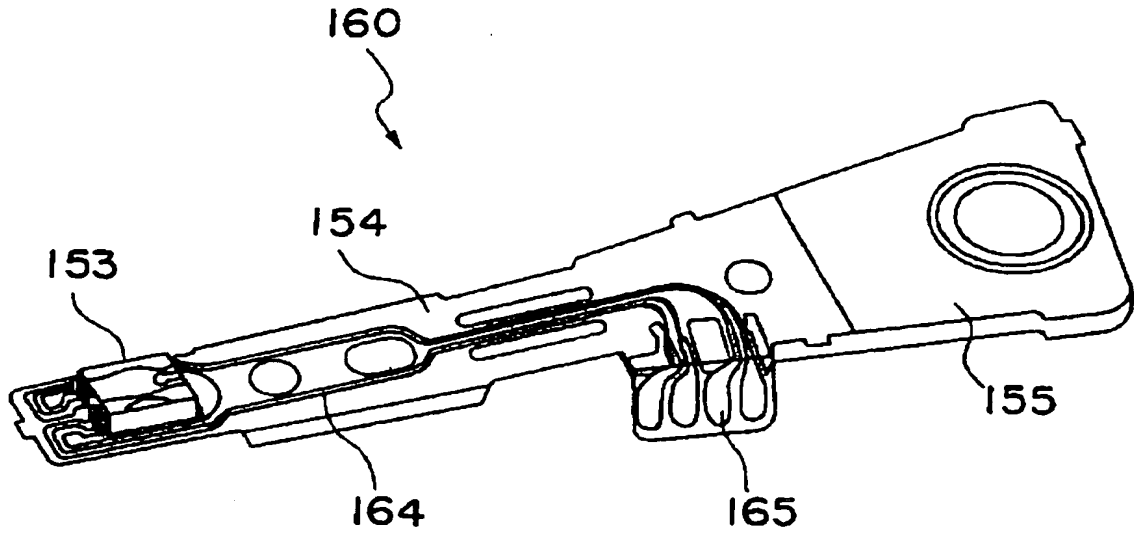


FIG.11

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